

NASA Facts

National Aeronautics and
Space Administration

Dryden Flight Research Center

P.O. Box 273
Edwards, California 93523
Voice: 661-276-3449
FAX 661-276-3566
pao@dfrc.nasa.gov



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NASA “Hyper-X” Program Demonstrates Scramjet Technologies

X-43A Flight Makes Aviation History



A modified Pegasus booster rocket ignites moments after release from the B-52B, beginning the acceleration of the X-43A over the Pacific Ocean in March of 2004. The X-43A vehicle is mounted on the nose of the rocket.

NASA made aviation history with the first successful flight of a scramjet-powered airplane at hypersonic speeds—speeds greater than Mach 5 or five times the speed of sound. Compared to a rocketpowered vehicle like the Space Shuttle, scramjet (supersonic combustion ramjet) powered vehicles promise more airplane-like operations for increased affordability, flexibility and safety for ultra highspeed flights within the atmosphere and into Earth orbit. Because they do not have to carry their own oxidizer, as rockets must, vehicles powered by airbreathing scramjets can be smaller and lighter— or be the same size and carry more payload.

Researchers have worked for decades to demonstrate scramjet technologies, first in wind tunnels and computer simulations, and now in an airplane in flight. Ultimate applications include future hypersonic

missiles, hypersonic airplanes, the first stage of two-stage-to-orbit reusable launch vehicles and single-stage-to-orbit reusable launch vehicles.

High-Risk, High-Payoff Program

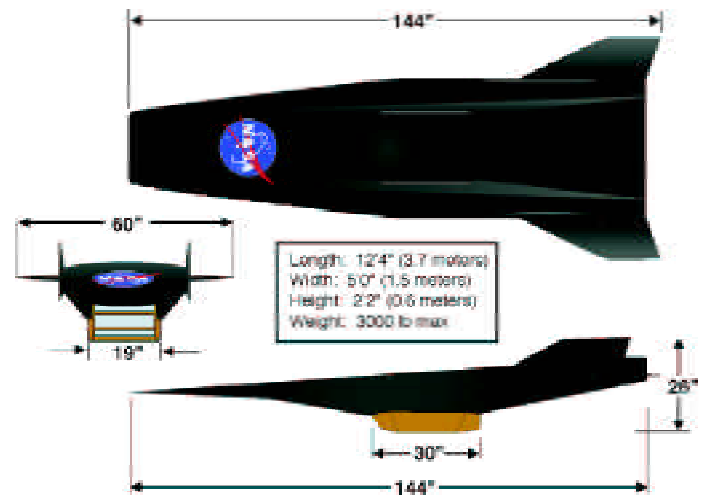
The eight-year, approximately \$230 million NASA Hyper-X program is a high-risk, high-payoff research program. It is attempting challenges never done before. No vehicle had ever flown at hypersonic speeds powered by an air-breathing scramjet engine before the successful flight of March 2004. In addition, the rocket boost and subsequent separation from the rocket to get to the scramjet test condition have complex elements that must work properly for mission success. Careful analyses and design were applied to reduce risks to acceptable levels; even so, some level of residual risk is inherent to the program.

Hyper-X research began with conceptual design and wind tunnel work in 1996. Three unpowered X-43A research aircraft were built. Each of the 12-foot-long, 5-foot-wide lifting body vehicles was designed to fly once. They are identical in appearance, but engineered with slight differences that simulate variable engine geometry, generally a function of Mach number. The first and second vehicles were designed to fly at Mach 7 and the third at Mach 10. At these speeds, the shape of the vehicle forebody serves the same purpose as pistons in a car, compressing the air as fuel is injected for combustion. Gaseous hydrogen fuels the X-43A. The first flight attempt in June 2001 failed when the booster rocket went out of control and the “full stack”—the booster rocket and X-43A combination—was destroyed by ground controllers. The second attempt at Mach 7, in March 2004, was highly successful. The third, and most challenging flight—at Mach 10—is set for fall 2004.

The Record-Breaking Flight

At Mach 7—or seven times the speed of sound—the X-43A research vehicle was traveling nearly 5,000 mph during the March 2004 flight, easily setting a world speed record for a jet-powered (air-breathing) vehicle. Guinness World Records has recognized the accomplishment and is listing the flight on their web site and in their next book of records.

The previous record was held by a ramjet-powered missile that achieved slightly over Mach 5. The highest speed attained by a rocket-powered airplane, NASA’s X-15 aircraft, was Mach 6.7. The fastest airbreathing, crewed vehicle, the SR-71, achieved

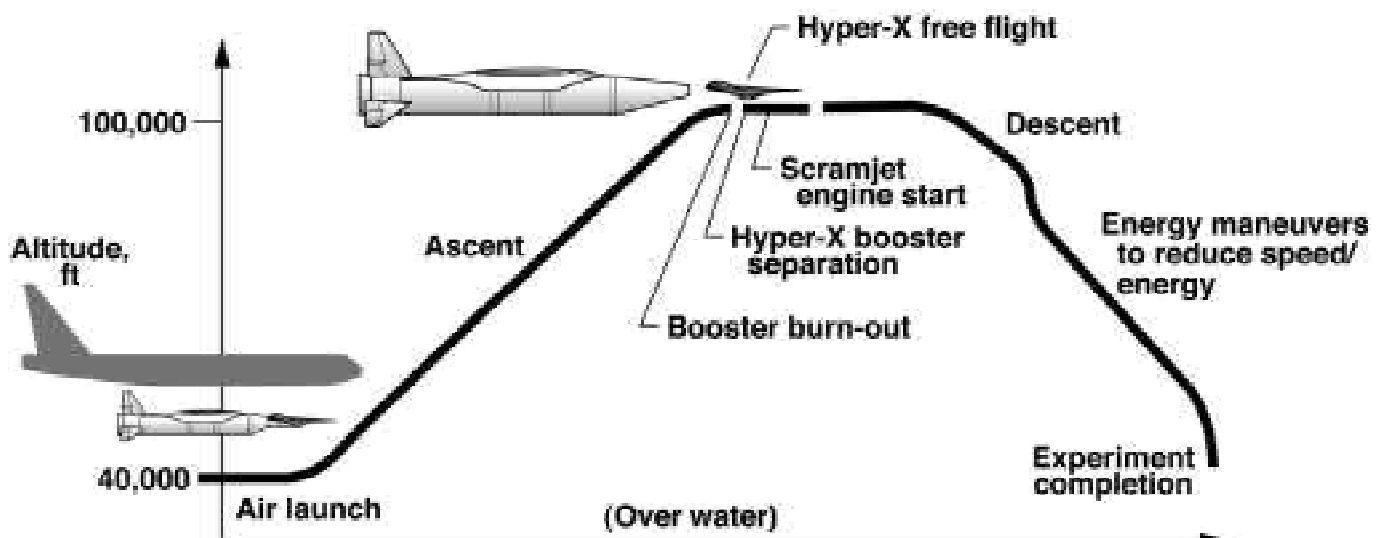


Hyper-X research vehicle configuration.

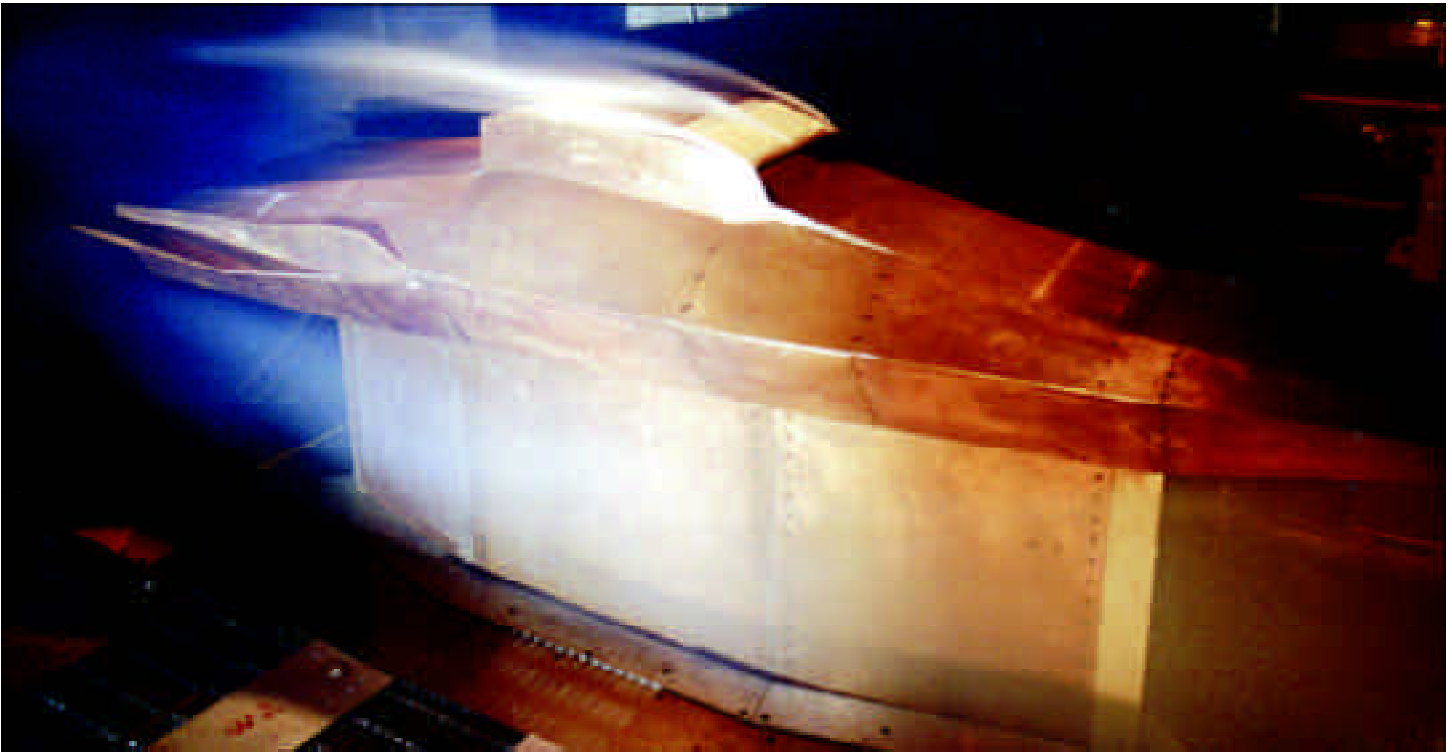
slightly over Mach 3. The X-43A more than doubled the top speed of the jet-powered SR-71.

The flight of the X-43A began with the stack being carried by a B-52B aircraft from NASA’s Dryden Flight Research Center to a point 40,000 feet over the Pacific, 50 miles west of the Southern California coast. At that point, the stack was dropped, and the booster lifted the research vehicle to test altitude and speed.

At 95,000 feet, the X-43A research vehicle separated from the booster and flew under its own power and preprogrammed control. The research vehicle was separated from the booster rocket by two small pistons. Shortly after separation, its scramjet engine operated for about ten seconds, demonstrating forward thrust in flight and obtaining unique flight data for an



Each of the Hyper-X research vehicles will achieve test speed and altitude with the help of the NASA Dryden B-52 aircraft and an expendable booster rocket, as shown in this simplified flight trajectory.



Wind tunnel tests were a necessary step before the first flight attempt, as in this Mach 7 test of a full-scale model with spare flight engine in Langley's 8-Foot High Temperature Tunnel.

airframeintegrated scramjet.

When the scramjet engine test was complete, the vehicle went into a high-speed maneuvering glide and collected nearly 10 minutes of hypersonic aerodynamic data while flying to a mission completion point, 450 miles due west in the Naval Air Warfare Center Weapons Division Sea Range off the southern coast of California.

Mach 10 Flight is Next

The last X-43A vehicle has additional thermal protection for the Mach 10 flight, since it will experience heating roughly twice that of the Mach 7 vehicle. Reinforced carbon-carbon composite material has been added to the leading edges of the vehicle's vertical fins to handle the higher temperatures.



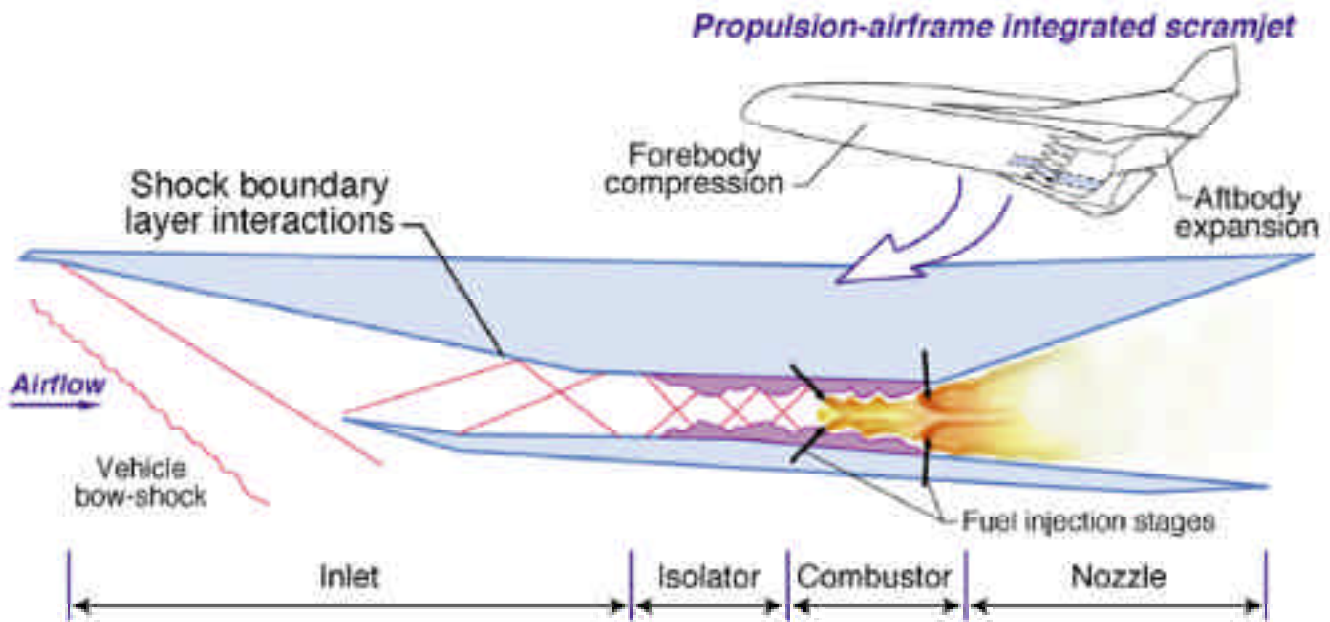
The Hyper-X program has significantly expanded the boundaries of air-breathing flight by being the first to fly a "scramjet" powered aircraft at hypersonic speeds

For the Mach 10 flight, which equates to approximately 7,000 mph, the booster rocket will launch the X-43A to 110,000 feet before it separates and the X-43A operates its scramjet. The research vehicle will travel about 850 miles before splashing into the ocean. As with the previous X-43A vehicles, it will not be recovered.

2001 Flight and Investigation

The first X-43A flight attempt was in June 2001. Unfortunately, the booster failed and had to be destroyed early in flight. As a result, the research vehicle was not tested because it never reached test conditions. Although no single contributing factor was found, the root cause of the problem was identified as the booster's flight control system. The booster failed due to inaccurate design models that overestimated the capability of the flight control system to operate within predicted flight conditions.

Numerous actions were taken in response to the findings. Wind tunnel tests were conducted to provide data to reduce atmospheric loads on the booster's control surfaces, more powerful booster fin actuators were added to overcome aerodynamic loads, and propellant was machined out of the Pegasus booster to enable launch at its normal launch altitude of 40,000 feet instead of 23,000 feet—as on the first flight—in order to reduce aerodynamic loads.



This simplified graphic illustrates how air and fuel mix at supersonic speeds inside a scramjet engine to propel the vehicle to many times the speed of sound. Supersonic speeds are greater than the speed of sound.

How Scramjets Work

A ramjet operates by subsonic combustion of fuel in a stream of air compressed by the forward speed of the aircraft itself, as opposed to a normal jet engine, in which the compressor section (the fan blades) compresses the air. Ramjets operate from about Mach 3 to Mach 6.

A scramjet (supersonic-combustion ramjet) is a ramjet engine in which the airflow through the whole engine remains supersonic. It is thought that a scramjet can operate from Mach 5-6 up to at least Mach 15. See illustration above.

Langley & Dryden-A Joint Effort

The Hyper-X Program managed by the Aeronautics Research Mission Directorate in Washington and is conducted jointly by the Langley Research Center, Hampton, Va., and the Dryden Flight Research Center, Edwards, Calif. Langley is the lead center and is responsible for hypersonic technology development. Dryden is responsible for flight research, hardware integration and testing.

NASA's Aeronautics Research Mission Directorate develops tools and technologies that can help trans-

form how the air transportation system operates, how new aircraft are designed and manufactured, and how our Nation's air transportation system can reach unparalleled levels of safety and security. ATK GASL (formerly MicroCraft, Inc.), Tullahoma, Tenn. and Ronkonkoma, N.Y., built the three X-43A research aircraft and engines. Boeing Phantom Works, Huntington Beach, Calif., designed the thermal protection and onboard systems. The booster is a modified Pegasus rocket built by Orbital Sciences Corp., Chandler, Ariz.

For more information, contact:

NASA Langley
Research Center
Office of Public Affairs
Hampton, VA 23681
(757) 864-6124
or

NASA Dryden Flight
Research Center
Office of Public Affairs
Edwards, CA 93523
(661) 276-3449

